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Perlaviciute, Goda; Steg, Linda; Hoekstra, Elisabeth J.; Vrieling, Leonie

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Original research article

Perceived risks, emotions, and policy preferences: A longitudinal survey among the local population on gas quakes in the Netherlands

Goda Perlaviciute*, Linda Steg, Elisabeth J. Hoekstra, Leonie Vrieling

University of Groningen, Faculty of Behavioural and Social Sciences, Environmental Psychology, Grote Kruisstraat 2/1, 9712 TS Groningen, The Netherlands

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ABSTRACT

Energy production can pose risks, such as nuclear accidents, oil spills, and earthquakes caused by gas production. Besides experts' evaluations of risks, appropriate risk assessment and management require knowledge about how people experience these risks and which mitigation measures they prefer. Media are often the sole source of information about public risk perceptions. Yet, media typically only report the most severe risks. By studying perceptions of different types of risks – among people with varying exposure to risks – we demonstrate how social science research can complement media reporting. We conducted a longitudinal questionnaire study into public risk perceptions of earthquakes caused by gas production in the province of Groningen, the Netherlands. While the media have reported multiple high risks and strong negative emotions, we found that people were mostly concerned about the risks for properties and for the image of the province of Groningen. Feeling powerless was the strongest negative emotion. People also evaluated mitigation measures as urgent but poorly implemented. Our results suggest that appropriate risk assessment and management need to follow a multi-method approach. This should incorporate multiple levels of analyses, including media reports, social science research on public risk perceptions, and experts' evaluations of risks.

1. Introduction

Energy production may pose serious risks. Examples include nuclear accidents, oil spills, water contamination and tremors from shale gas production, leakages from CO_2 capture and storage, and breaks of the dams of hydro-power plants. As such, energy production poses not only technical but also societal challenges [1–3]. Besides experts' evaluations of risks, adequate risk assessment and management require knowledge about how people perceive and experience these risks and which mitigation measures they prefer. Media reports are often the sole source of information about public risk perceptions. We argue that relying solely on media reports may provide a narrow understanding of public risk perceptions and preferences, and may therefore hinder adequate and responsible decision making. We aim to demonstrate in this paper that social science research has important added value as a source for appropriate risk assessment and management. Therefore, social science needs to be incorporated together with other types of analyses, such as media reports and experts' evaluations of risks.

1.1. Assessing perceived risks

Policy makers often (need to) rely on the media to assess public risk perceptions associated with energy production. Yet, research suggests that people who perceive highest risks and who are most concerned about certain types of energy production are most likely to engage in actions such as protests and public meetings [4], making it more likely that their views are overrepresented in the media. Indeed, there is a trend in the media to engage the audience by reporting "scarce stories" and stressing high rather than low risks [5]. Such media analysis is informative because it signals whether there are societal concerns about energy production and it reveals which risks are most prominently discussed. At the same time, however, if policymakers rely *only* on the media, they may get a narrow understanding of public risk perceptions and preferences. For example, policymakers may overgeneralize the high risk perceptions reported in the media to the general population and think that everyone perceives the risks as equally high. This can be counterproductive. Policymakers may not further communicate the risks to people – and encourage them to take or accept actions to protect themselves against these risks – if they conclude from the media reports that people are already motivated to take these actions [6].

Social science research can complement media analysis by systematically studying the extent to which the risk perceptions presented in the media are shared by the population in general. Such research can reveal whether public risk perceptions in general align with or differ

* Corresponding author.
E-mail address: g.perlaviciute@rug.nl (G. Perlaviciute).

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from media reports and/or experts' evaluations of risks, and why this could be the case. For example, studies have found that people who are exposed to high risks may downplay these risks for themselves – a result of the optimism-bias [6]. Students in California who lived in dormitories that were not earthquake-proof tended to evaluate the risks of earthquakes for themselves as lower than students living in earthquake-proof dormitories [7]. Optimism biases may have detrimental consequences if they reduce people's motivation to take action to protect themselves against risks (e.g., the risk of earthquakes [8,9], floods [10,11]; see also [6,12]). In case people do not face high risks themselves, they may hear about the high risks of energy production activities from the media and/or from other people. An interesting question here is how they integrate such information into their risk perceptions and whether they distinguish between the risks for themselves and the risk for others.

The media typically reports that people are concerned about many risks of energy production [13]. Yet, for effective risk assessment and management, it is important to understand how people perceive *different types* of risks and which risks they perceive as most likely and most severe. Such knowledge can complement the experts' evaluations of risks in setting priorities in risk mitigation policy. Furthermore, it is important to not only understand cognitions but also consider the emotions that people experience towards (the risks of) energy production, since such emotions may play an important role in people's willingness to take action and/or accept policy to protect themselves against risks [6]. Besides studying emotions that may motivate people to protect themselves against risks, such as anger, it is crucial to map out emotions that may inhibit people to take protective measures, such as feeling powerless [14].

Furthermore, in order to better understand the dynamics of risk perception, it is necessary to study how perceived risks, emotions, and preferences for mitigation measures develop over time. For example, three months after the California earthquake in 1989, Californian university students evaluated their own risk of being hurt in a natural disaster – such as earthquake – as lower than the same risk for an average student at their university and for an average person of their age living in their region, which suggests optimism biases [15]. Yet, optimism biases were not observed immediately after the earthquake [15]. Furthermore, research suggests that experience of an earthquake eliminated optimism biases five months after the earthquake [16]. Studies employing longitudinal research designs to study changes in risk perceptions are however rare [17]. Yet, perceived risks of energy production are likely to be continuously influenced by multiple factors, such as people's experience of risks, media attention to these risks, and mitigation measures that have been implemented. Monitoring risk perceptions over time in such complex contexts is crucial for appropriate risk assessment and management, and for evaluation of the effectiveness of mitigation policies.

Based on the above, we argue that appropriate assessment and mitigation of risks posed by energy production should follow a multi-method approach. This should incorporate different levels of analyses, including social science research on public risk perceptions, media analysis, and experts' evaluations of risks. In the present study, we demonstrate the added value of the first approach: social science research to better understand public risk perceptions, emotions, and preferences for mitigation measures. To illustrate, we studied risks associated with earthquakes caused by gas production in the province of Groningen, the Netherlands.

1.2. Earthquakes caused by gas production in the province of Groningen

Natural gas forms the largest share of the total energy mix in the Netherlands; the total share was 40% in 2014 [18]. Natural gas in the Netherlands is the primary energy source for households for heating houses and water and for cooking [19]. NAM (Nederlandse Aardolie Maatschappij) operates gas extraction; the company is owned by Shell and ExxonMobil. Decisions about gas extraction are made by a partnership between NAM and EBN (Energie Beheer Nederland); the latter is a state-owned company. The Dutch government is financially involved in gas extraction via EBN [20]. The income from domestic use and export of gas to the national budget was 5.7 billion euros in 2016 [21]. A recent study revealed that a representative sample of the Dutch population evaluated gas positively in terms of consequences for the Dutch economy, people's daily comfort, and meeting energy needs in the Netherlands [22]. Gas was evaluated neither negatively nor positively with regard to consequences for the environment and people's health and safety, and rather negatively on the financial costs for people [22].

Recently gas production in the Netherlands has been much debated because of earthquakes induced by gas production. The earthquakes have taken place in the province of Groningen in the north of the country, where most of the gas is produced. Multiple earthquakes in the region have been observed, with a maximum strength of 3.6 on the Richter scale (the Huizinge earthquake in August 2012). The intensity and frequency of earthquakes varies across regions in the province of Groningen. In January 2013, the State Supervision of Mines (SoDM) published a report stating that stronger earthquakes can be expected if gas production continues at the same level [23]. This demands legitimate policy and effective risk mitigation measures in order to protect local communities and safeguard their quality of life. So far, the media have been a dominating source of information about public responses to earthquakes caused by gas production. Below, we summarise a published analysis of media coverage on this topic [13].[1] Next, we describe the mitigation measures that have been implemented so far. Following this, we introduce the key research questions and the related findings of the current longitudinal survey.

1.2.1. Risk perceptions in the media

Since the strongest earthquake in August 2012 there has been increased attention to the risks of earthquakes in the media and in public and policy debate. A qualitative analysis of the media coverage on earthquakes suggests that this corresponded with increasing concern about earthquakes among local communities [13]. According to the media analysis, public concern was amplified by the SodM report [23], which stated that even stronger earthquakes may happen in the future: "People in Groningen had known about the earthquakes for years and had lived with them without much concern, but the SodM report with its prognosis of increasing severity of earthquakes and increased impacts led many people to reconsider their opinions, leading to considerable consternation at the local level" [[13], p. 1]. The media analysis further suggests that people became increasingly concerned about many risks of earthquakes, such as damage to houses and drop in house values, as well as risks for physical and mental health. Furthermore, strong emotions, such as anxiety, fear, insecurity, and anger, have been depicted in the media [13].

1.2.2. Mitigation measures

In January 2014, nine municipalities in the earthquake region, the national government, and the province of Groningen agreed upon a package of mitigation measures [24]. Some of these measures are focused on preventing and/or reducing the risks and damage caused by earthquakes. For example, in March 2014, the minister of economic affairs decided to reduce gas production in and around the municipality of Loppersum, which has been most affected by the earthquakes [25]. Other examples are reinforcing houses and compensating people for damage to their houses and the drop in house values. The other measures are aimed at safeguarding or improving quality of life in the region and do not specifically target the risks of earthquakes. Examples are providing facilities such as fast internet and sports

[1] The media analysis was conducted mostly in 2013 [13].

facilities, investing in renewable energy sources in the region, and creating employment by hiring local companies to repair and reinforce houses (note that the latter measure is closely related to measures aimed at reducing the risks and damage caused by earthquakes). These measures have been implemented to some extent and are planned to be implemented further in the future. Yet, from the media analysis it seems that people are generally not satisfied with measures taken so far [13].[2] On the basis of this, however, it is difficult to judge whether people disregard all the measures or they support some measures more than others. Also, it is not clear, based on the media reporting, whether people do not support these measures at all or whether they mainly object the way these measures are implemented.

An important question is to what extent the perceived risks, emotions, and policy preferences presented in the media reflect the views of the general population in the province of Groningen. Also, which risks are people most concerned about, which emotions do they experience most strongly, and how do they evaluate different types of mitigation measures? Given that people live in different regions that vary in exposure to earthquakes, how do they see the risks for themselves and the risks for other inhabitants of the province of Groningen? Answering these questions requires a social science study of risk perceptions among a representative sample of the population of the province of Groningen.

1.3. Current research

We conducted a longitudinal questionnaire study among residents in the province of Groningen from three regions varying in exposure to earthquakes. We studied public perceptions of different types of risks of earthquakes and measured how people in different regions perceive the risks for themselves and for other people in the province of Groningen. Also, we studied which emotions people experience and how they evaluate different mitigation measures that were implemented.[3] Importantly, we monitored people's responses over time. During the time of the study, earthquakes reoccurred, there was increased media attention to the related risks, and mitigation measures were taken. Fig. 1 illustrates the timeline of the study, as well as the number of media reports on the (risks of) earthquakes and the earthquakes with a magnitude 3 or higher on Richter scale that took place in that period. The first research phase took place about a year after the strongest earthquake in Huizinge. The second research phase took place shortly after the package with mitigation measures was introduced, and the third research phase took place about half a year later.

2. Method

2.1. Regions

The data was collected in three regions within the province of Groningen that vary in exposure to earthquakes. Exposure was assessed on the basis of magnitude, intensity, and frequency of earthquakes, based on the data from the Dutch Royal Meteorological Institute at the time before the first research phase (www.knmi.nl). Region 1 was most exposed to earthquakes and included the municipality of Loppersum. Region 2 was less exposed to earthquakes and included the municipalities of Bedum, Appingedam, and Slochteren. Region 3 was least exposed to earthquakes and included the municipalities of Zuidhorn, Groningen, and Delfzijl.

[2] The media analysis was conducted before the above-mentioned package of mitigation measures was introduced. Yet, some mitigation measures, for example compensating for damages, had already been implemented before; the new package included improvement of implementation of these measures.

[3] Measures in the questionnaire that are beyond the scope of this paper are not discussed here. The full questionnaire is available from the corresponding author.

2.2. Procedure

People were approached at their homes by trained research assistants and asked to participate in a study on their opinion about gas production and earthquakes in the province of Groningen.[4] A computer programme was used to make a random selection of streets within each region and the research assistants went to at most five homes within the selected streets. The research assistants followed a strict protocol for approaching people. They first briefly introduced the goal of the study and asked whether people would be willing to participate by filling in a questionnaire, which would take them about 30 min. If they agreed to participate, respondents received the questionnaire, which they could fill in by themselves. The questionnaires were later picked up upon appointment. Also, respondents received a flyer with general information about the study and contact details in case of questions. Before filling in the questionnaire, participants were asked to sign an informed consent form. As a token of appreciation for their time and effort, participants received a 10 euros voucher for a local bakery. After each research phase, a summary of main findings was sent to respondents (i.e., those who were willing to participate in follow-up research and therefore provided their contact details; see below) and were published on the research website and in the regional press. To not affect participants' subsequent responses, we framed these summaries very neutrally, describing the means of key variables and relative differences between the three regions and between different types of perceived risks, emotions, and evaluations of mitigation measures.

2.2.1. Monitoring

In each phase, respondents were asked whether they would like to participate in follow-up research. If so, a unique code had to be created by respondents, in order to later match their responses across multiple phases while assuring respondents' privacy.[5] Respondents who agreed to participate again were also asked for their address for contacting them again. The contact information was stored separately and could not be linked to responses in the questionnaire. Due to (potential) drop-out of respondents in the course of the study (e.g., declining to participate again, not being at home at the time of the subsequent data collection phase), we also recruited new respondents in the second and third phase, using the procedure described above. As such, the current design was a mixture of a cross-section and longitudinal panel design [17].

2.2.2. Respondents

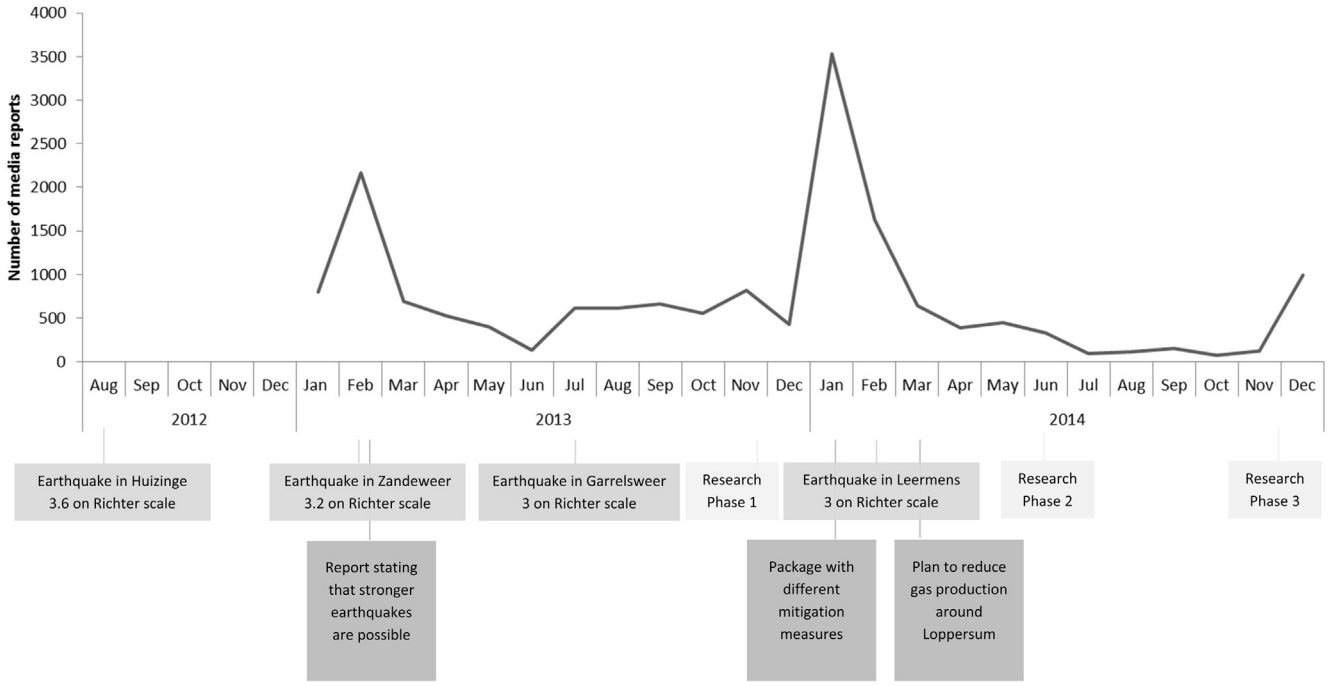
The responses of 13 participants who did not sign the informed consent form were excluded from the analyses.[6] This resulted in the total of 1232 responses. Table 1 displays the number of responses per region per phase and specifies how many new respondents were recruited in phase 2 and phase 3.

Socio-demographics characteristics of respondents across research phases are displayed in Table 2. The socio-demographic characteristics are similar across the three phases.

[4] The person who opened the door was invited to participate, although we did not control (and believe this is not necessary for the study purpose) who in the household completed the study in the first instance. During follow-up visits, we stressed that the same person who completed the questionnaire the previous time(s) would need to complete the questionnaire again.

[5] In order to be matched, the codes of the same participant needed to be identical at every phase of data collection. In case a participant provided incomplete codes or slightly different codes every time, we were not able to match his/her responses and could only treat them as independent rather than follow-up responses.

[6] If participants did not sign the informed consent form but still indicated to be willing to participate in subsequent research phases, their responses were included in the analyses.



Note. The number of media reports per month is based on media messages about earthquakes and subsidence (a closely related topic) in newspapers, magazines, and news websites. Source: media monitoring and analysis company Publistat.

Note. Information regarding strength and location of earthquakes was retrieved from http://feitenencijfers.namplatform.nl/geokaart/

Fig. 1. Timeline of the three study phases.

Table 1
Number of responses per phase and per region, and number of new respondents in phase 2 and phase 3.

	Phase 1	Phase 2	Phase 3[a]
Total	390 (100%)	429 (100%)	413 (100%)
New respondents		255 (59%)	160 (39%)
Region 1	141 (36%)	139 (32%)	157 (38%)
Region 2	126 (32%)	144 (34%)	149 (36%)
Region 3	123 (32%)	146 (34%)	101 (24%)

[a] The percentages across regions do not add up to 100% because region information was missing for 6 cases.

2.3. Measures

The items measuring perceived risks of earthquakes, emotions, and evaluations of mitigation measures are displayed in Table 3.

2.3.1. Perceived risks of earthquakes

Respondents reported to what extent they think it is likely (on a 7-point scale ranging from 1 very unlikely to 7 very likely) that the earthquakes pose various risks for respondents themselves, for inhabitants of the province of Groningen, and several other risks (Table 3).

2.3.2. Emotions towards earthquakes

Respondents reported which different emotions they experience when thinking about the earthquakes on a 7-point scale ranging from 1 not at all to 4 moderately to 7 very strongly (Table 3).

2.3.3. Evaluations of mitigation measures

In all research phases, participants indicated on a 7-point scale to what extent they think gas production from the Groningen gas field should stop (1) or stay the same (7). Additionally, in phase 2, participants evaluated different types of mitigation measures that had been introduced before phase 2 took place. We included four measures aimed at preventing and/or reducing the risks and damage caused by earthquakes and three measures that are not directly targeted at reducing the risks of earthquakes but are aimed at increasing people's quality of life. Respondents indicated on a 7-point scale how urgent (1 not at all urgent – 7 very urgent) they find these measures, how well these measure are being implemented (1 not at all well implemented – 7 very well implemented), and to what extent these measures are effective (1 not at all effective – 7 very effective) in achieving relevant goals (Table 3).

2.4. Analyses

We first examined differences between regions in each research phase, following a cross-sectional design. To make sure that observations were independent across phases, we only included respondents who participated in one of the research phases for these analyses (n = 515). We tested differences in perceived risks and emotions between regions in each research phase by using MANOVA. Next, we used one-way ANOVA to compare between regions the extent to which people thought that gas production should stop or stay the same. We also tested differences between regions in evaluations of mitigation measures (which were only studied in phase 2) by using MANOVA. We used the Bonferroni procedure for the post-hoc analyses. We analysed the different types of perceived risks, emotions, and evaluations of different mitigation measures separately, instead of compiling these multiple items into overall scales. We followed this procedure in order to provide a more nuanced counterpoint to the media analysis and to give detailed insight in which risks are perceived as most likely, which emotions are strongest, and which mitigation measures people prefer.

Second, we examined differences across time following a longitudinal panel design; here, we selected respondents who participated in all research phases (n = 137). We tested differences over time by using repeated measures (RM) ANOVA's and used the LSD procedure for the post-hoc analyses. When the assumption of sphericity was violated, we used the Bonferroni procedure for the post-hoc analyses and Huynh-Feldt as an estimate for the correction for the degrees of freedom.

Table 2
Socio-demographic characteristics per research phase.

		Phase 1	Phase 2	Phase 3
Gender	Female	169 (43%)	195 (45%)	176 (43%)
	Male	212 (54%)	225 (52%)	232 (56%)
	Missing values	9 (2%)	9 (2%)	5 (1%)
Age (in years)	*M* (*SD*)	52.15 (14.91)	52.66 (14.59)	54.81 (13.71)
	Minimum	19	18	20
	Maximum	90	84	84
	Missing values	12 (3%)	10 (2%)	6 (1%)
Highest completed education	Primary school	8 (2%)	5 (1%)	3 (1%)
	Lower vocational education	34 (9%)	37 (9%)	29 (7%)
	Secondary (vocational) education	142 (36%)	143 (33%)	146 (35%)
	Higher (vocational) education	141 (36%)	135 (31%)	113 (27%)
	Scientific education (university)	47 (12%)	38 (9%)	25 (6%)
	Other	6 (2%)	4 (1%)	4 (1%)
	Missing values	12 (3%)	67 (16%)	93 (22%)
Income per month	< €1000	17 (4%)	14 (3%)	12 (3%)
	€1000–€2000	98 (25%)	113 (26%)	94 (23%)
	€2000–€3000	109 (28%)	107 (25%)	95 (23%)
	€3000–€4000	79 (20%)	72 (17%)	74 (18%)
	€4000–€5000	30 (8%)	26 (6%)	31 (8%)
	> €5000	14 (4%)	7 (2%)	4 (1%)
	Missing values	43 (11%)	90 (21%)	103 (25%)
Household composition	Alone	59 (15%)	52 (12%)	46 (11%)
	With children	12 (3%)	17 (4%)	13 (3%)
	With partner	161 (41%)	160 (37%)	146 (35%)
	With partner and children	139 (36%)	130 (30%)	120 (29%)
	Other	9 (2%)	8 (2%)	5 (1%)
	Missing values	10 (3%)	62 (14%)	83 (20%)
Number of years of residence in the area	*M* (*SD*)	30.59 (19.66)	31.95 (19.30)	34.40 (19.63)
	Minimum	.50	1	1
	Maximum	83	83	80
	Missing values	9 (2%)	63 (15%)	84 (20%)

3. Results

3.1. Perceived risks of earthquakes

Perceptions of the different risks of earthquakes in the three regions and across the three study phases are depicted in Fig. 2; details for group differences are given in Appendix A. Respondents thought it is highly likely that the earthquakes will have negative consequences for properties, namely damage to houses and reduced value of houses. While respondents perceived relatively high risks for their own properties, they generally perceived even higher risks for properties of inhabitants of the province of Groningen. This was most evident in the regions that are less exposed to earthquakes, which makes it unlikely that the effects are due to optimism biases. In all study phases, people in most affected regions saw significantly higher risks for their own properties than people in less affected regions. Yet, everyone perceived the risks for properties for people in Groningen in general as high, with no significant differences across regions.

All respondents evaluated the likelihood that the earthquakes would result in a negative image of the province of Groningen as rather high, with mostly no significant differences across the regions.

Perceived risks of physical injury, stress and worry, as well as reduced quality of living – for respondents themselves and for inhabitants of the province of Groningen – were seen as relatively lower. Again, residents in more affected regions saw their own risks as higher than those in less affected regions. Everyone saw these risks as relatively high for inhabitants of the province of Groningen, with mostly no significant differences across the regions.

The risk of damage to nature and the environment, and the risk of impaired relationships between people in one's neighbourhood were perceived as relatively low, with mostly no significant differences across the regions.

Significant increases in risk perceptions over time were found, despite the implementation of the mitigation measures. For people themselves, the perceived risk of damage to houses, drop in house values, stress and worry, and reduced quality of living increased. For inhabitants of Groningen, the perceived risk of a drop in house values, stress and worry, and reduced quality of living increased. Perceived risk of a negative image of the province of Groningen also increased. However, differences between phase 1 and phase 2, and between phase 2 and phase 3 were not always statistically significant (details are given in Appendix A).[7]

3.2. Emotions

Mean evaluations of emotions towards earthquakes in the three regions and across the three study phases are depicted in Fig. 3; details for group differences are given in Appendix B. Respondents most strongly felt powerless when thinking about the earthquakes. Other emotions – namely feeling fearful, angry, disappointed, uneasy, terrible, and feeling calm – were less strong. Significant differences were found between regions in emotions towards earthquakes at phase 1 and phase 2 but not at phase 3. People in more affected regions tended to report stronger negative emotions than people in less affected regions.

Negative emotions increased over time. In phase 3, respondents reported feeling more angry, disappointed, uneasy, terrible, and powerless compared to phase 1, They also felt more terrible in phase 2 compared to phase 1. Moreover, they reported feeling more angry, disappointed, and uneasy in phase 3 compared to phase 2 (Appendix B).

3.3. Evaluations of mitigation measures

The mean scores for the extent to which respondents thought gas production from the Groningen gas field should stop or stay the same were around or below the mid-point of the scale (see Fig. 4). This suggests that respondents thought that gas production should at least be reduced. In all study phases, the regions significantly differed in the extent to which people thought that gas production should stop or stay the same; details for group differences are given in Appendix C. Respondents in the most affected region had a greater tendency to think that the gas production should stop than respondents in less affected regions. Over time, there was an increase in the extent to which respondents believed that gas production should be reduced; this difference was statistically significant only between phases 1 and 3 (Appendix C).

Evaluations of the other mitigation measures that were evaluated in phase 2 are depicted in Fig. 5. The measures aimed at preventing and/or reducing the risks and damage caused by earthquakes (i.e., reducing gas production around Loppersum; reinforcement of houses, buildings, roads and dikes; adequate regulation for handling damage due to the earthquakes; and adequate compensation for drop in house values due

[7] Please note that differences over time were tested only for respondents who participated in all study phases. The group means for these participants are comparable to the group means for those who participated once (see figures; exact means can be requested from the first author). This also applies for further analyses of emotions and evaluations of mitigation measures.

Table 3
Measures of perceived risks of earthquakes, emotions towards earthquakes, and evaluations of mitigation measures.

Perceived risks of earthquakes				
Perceived risks for people themselves	*I consider […] because of the earthquakes* [damage to my house] [drop in the value of my house] [physical injury for myself or my family] [stress and worry for myself or my family] [reduced my quality of living]			1 very unlikely – 7 very likely
Perceived risks for inhabitants of the province of Groningen	[damage to houses of inhabitants of the province of Groningen] [drop in the value of houses of inhabitants of the province of Groningen] [physical injury for inhabitants of the province of Groningen] [stress and worry for inhabitants of the province of Groningen] [reduced quality of living of inhabitants of the province of Groningen]			
Perceived other risks	[damage to nature and the environment] [that the image of the province of Groningen will be negative] [impaired relationships between people in my neighbourhood]			
Emotions towards earthquakes				
When I think about earthquakes as consequence of gas production from the Groningen gas field, I feel… …fearful …angry …calm …disappointed …uneasy …terrible …powerless				1 not at all – 4 moderately – 7 very strongly
Evaluations of mitigation measures				
I think that gas production from the Groningen gas field should…		1 stop – 7 stay the same		
	Other mitigation measures evaluated in phase 2:	*I consider this measure…*		
				1 not at all – 7 very effective in…[a]
Preventing and/or reducing the risks and damage caused by earthquakes	Reducing gas production around Loppersum	1 not at all urgent – 7 very urgent	1 not at all well implemented – 7 very well implemented	…improving safety
	Reinforcement of houses, buildings, roads and dikes			…improving safety
	Adequate regulation for handling damage due to the earthquakes			…compensating inhabitants for damage
	Adequate compensation for drop in house values due to the earthquakes			…compensating inhabitants for damage
Increasing quality of life	Investing in facilities, such as installing fast internet, improving public transport, and sports and play facilities			…improving liveability
	Investing in local production of renewable energy (for example solar energy)			… increasing the value of houses
	Creating employment by hiring local companies to repair and reinforce houses[b]			… strengthening the regional economy

Note. For all items translations from Dutch are given.
[a] Different goals were indicated for different mitigation measures, as illustrated in the table.
[b] This measure is closely related to measures aimed at preventing and/or reducing the risks and damage caused by earthquakes.

to the earthquakes) were evaluated as somewhat more urgent than the measures aimed at safeguarding or improving quality of life in the region (i.e., investing in facilities, such as installing fast internet, improving public transport, and sports and play facilities; and investing in local production of renewable energy such as solar energy). While most measures were seen as rather urgent, they were not evaluated as very effective and people were not very positive about the way these measures were implemented. Creating employment by hiring local companies to repair and reinforce houses was seen as particularly urgent and effective for achieving the relevant goal (i.e., strengthening

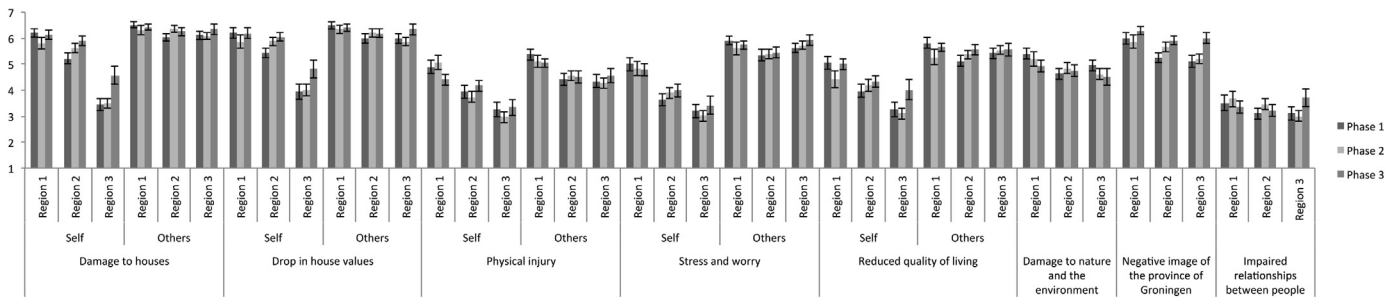


Fig. 2. Perceived risks of earthquakes in the three regions and across the three study phases.

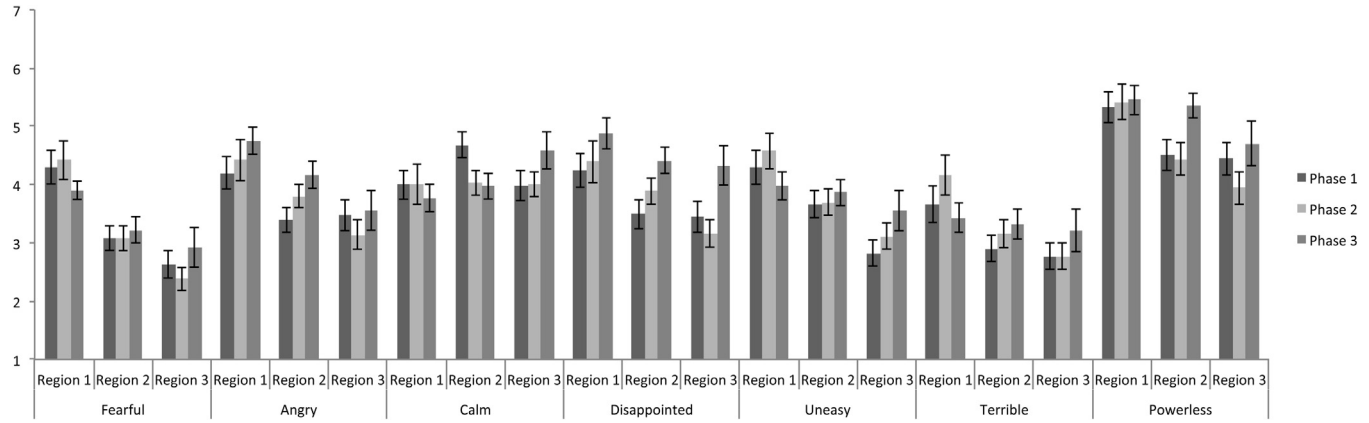


Fig. 3. Emotions towards earthquakes in the three regions and across the three study phases.

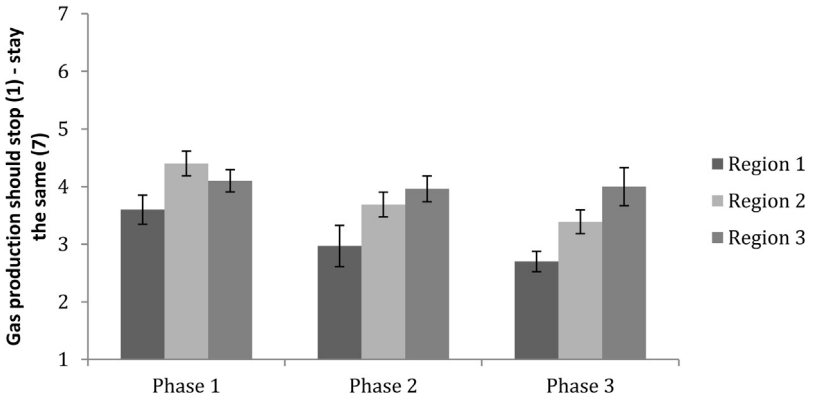


Fig. 4. Extent to which people think gas production should stop (1) or stay the same (7) in the three regions and across the three study phases.

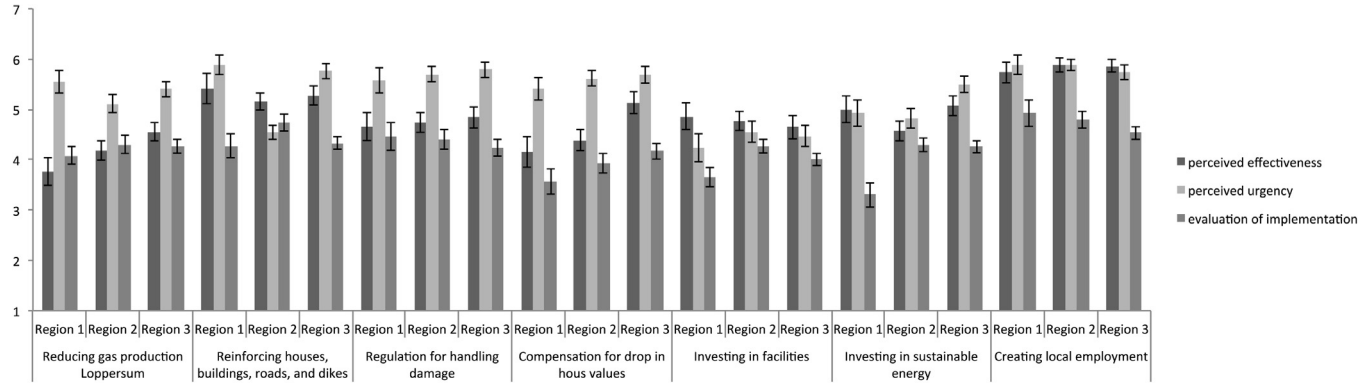


Fig. 5. Evaluations of mitigation measures across the three regions.

the regional economy); yet, the implementation of this measure was also not evaluated very positively.

Respondents in less affected regions evaluated some mitigation measures as somewhat more effective, urgent, or well implemented than respondents in more affected regions. But in general evaluations of mitigation measures were similar across regions (Appendix D).

4. Discussion

Energy production may pose serious risks. Besides experts' evaluations of such risks, appropriate risk assessment and management require knowledge of how the public perceive and experience the risks and which mitigation measures they prefer. Decision makers often (need to) rely on media coverage on public risk perceptions, but the media may over-represent the perspective of people who perceive high risks and experience strong negative emotions. As a result, decision-makers may get a narrow view of public risk perceptions, which can undermine responsible decision making about energy production. We argue that social science research can provide an important contribution to risk assessment and management, by studying which risks and emotions are most prominent among the population in general, and which mitigation measures people in the affected region prefer. Furthermore, monitoring risk perceptions over time can provide insights into how risk perceptions are continuously influenced by multiple factors, such as people's experience of risks, media attention to these risks, and mitigation measures that have been implemented. We addressed these questions in a longitudinal study on public perceptions of risks, experienced emotions, and evaluations of mitigation measures associated with earthquakes caused by gas production in the province of Groningen.

Our results provided more nuance to the media analysis by revealing which specific perceived risks and emotions people in the

region experience, and how they evaluate various mitigation measures that have been implemented. While the media suggest that people are very concerned about many earthquake-associated risks in the province of Groningen, we found that people perceived some risks as more likely than other risks. People reported highest perceived risks for properties – namely damage to houses and drop in house values – and for the image of the province of Groningen. In contrast, they evaluated the risks of physical injury, stress and worry, reduced quality of living, damage to nature and the environment, and impaired relationships between people in one's neighbourhood as less likely. Notably, most of the mitigation measures that have been implemented are aimed at compensating people for damaged properties and preventing further damages, and therefore seem to focus on people's prominent concerns. Yet, our findings indicate that people still perceive these risks as high. This could be due to multiple factors, including the reoccurring earthquakes and increased media focus on high risks. It may also be a result of people thinking that the mitigation measures are not well implemented, as found in this study. These findings suggest that it is indeed important to incorporate multiple levels of analyses – including media reports, social science research on public risk perceptions, and experts' evaluations of risks – in order to identify the most prominent risks that should be prioritized in policy making. Notably, policy makers are not only responsible for addressing the most prominent risks that people perceive but, more generally, for protecting people against the most acute risks, even if these risks may not be prominent in public concern.[8]

Differences in peoples' evaluations of their own risks corresponded with the exposure to earthquakes in the area in which they live. People in the region most affected by earthquakes evaluated their own risks as highest, whereas people in less affected regions perceived their own risks as lower. Notably, people in all regions perceived the risks for inhabitants of the province of Groningen in general as relatively high. Several factors could play a role here, including media reports about high risks as well as mitigation measures that are generally not seen as very well implemented. Future (experimental) studies could systematically investigate the unique effects of such factors on public risk perceptions.

As may be expected, the negative emotions were somewhat stronger in the regions more exposed to earthquakes. Yet, on average, the evaluations of negative emotions were around the midpoint of the scale, which was labelled as "moderate" ("matig" in Dutch). Only the feeling of powerlessness was relatively strong. This is an important finding, since feeling powerless may prevent people from taking risk protective measures. Future research could study whether feeling powerless indeed prevents people from taking effective action to protect themselves against the risks, for example using money received as compensation for damage to pay for repair or reinforcements of their homes. Additionally, future research could investigate which factors influence feeling powerless and what are effective strategies to mitigate such feelings. In case of energy production, people themselves have little control over the related risks and need to rely on responsible actors – such as the government and industry – for risk assessment and management. The way these actors manage (or do not manage) the risks and the extent to which people trust these parties may affect the feeling of powerlessness. Additionally, future research could systematically study the conditions under which certain risks and hazards evoke strong negative emotions.

Respondents thought that gas production from the Groningen gas field should be reduced to some extent. In the later research phases this increased, with respondents more strongly believing gas production should be decreased. The more people were exposed to earthquakes, the more they thought that gas production should stop or be reduced. Yet, on average, people did not think that gas production should stop completely. This may be due to gas being perceived as beneficial for the national economy and energy security, and as a comfortable energy source [22]. While the current study focused primarily on perceived risks of gas quakes, future studies could investigate the relationships between perceived risks, on the one hand, and perceived national as well as regional benefits of gas production, on the other hand. This would provide additional insights into how people weigh different negative and positive consequences of energy production and how they incorporate these different consequences in their acceptability ratings of different energy sources.

Furthermore, people evaluated measures that are aimed at preventing and/or reducing the risks of earthquakes as particularly urgent. In contrast, measures that do not directly target the risks of earthquakes (e.g., investing in various facilities) were seen as somewhat less urgent. Interestingly, creating employment by involving local companies in recovering and reinforcing houses was seen as very urgent and effective measure to strengthen the regional economy. This suggests that people preferred measures that tackle the risks of earthquakes *and* improve quality of life. Preference for this measure may be partly due to the fact that some parts of the province of Groningen (e.g., municipalities of Loppersum, Delfzijl, Appingedam) are facing economic decline due to a shrinking population [26]. Similarly, local communities may consider it fair to receive additional benefits for the risks they bear because of gas production. Future studies are needed to examine the effects of the different characteristics of mitigation measures on people's evaluations of these measures.

While people perceived many mitigation measures as urgent, they were not very positive about the effectiveness of most measures and the way these measures are implemented. This may be one of the key factors explaining why perceived risks and negative emotions did not decrease over time; if anything, they increased. This again emphasizes that it is important to incorporate knowledge about public risk perceptions in addition to experts' evaluations of risks. Through this, we can better assess how the current measures address important risks and people's concerns about these risks, as well as how these measures can be optimized.

4.1. Limitations and future research

This research was a first attempt to study how perceived risks of energy production form and develop in a complex context of the reoccurring risks, media attention to these risks, and introduction of mitigation measures. We conducted a longitudinal study to reveal and monitor people's risk perceptions, emotions, and preferences for mitigation measures in such a complex context. Yet, field study designs cannot explain the causal relationships between the observed public views and contextual factors. Future experimental studies could investigate these relationships. For example, scenario studies could introduce mitigation measures that vary on certain aspects and test how these different aspects influence people's evaluations of the mitigation measures, as well as their risk perceptions and emotions.

We followed a door-to-door procedure for data collection in order to reach people who may normally not express their opinion, for example in the media. Yet, not everyone whom we approached agreed to participate (please note that we did not record the response rate), and the sample may therefore not be fully representative of the relevant population. Yet, a similar procedure has resulted in a high response rate in prior research (e.g., 79.5% in a study on quality of life in residential environments [27]). Future studies could try to further optimize the data collection procedures and how representative these samples are of the general population.

Furthermore, the aim of the current research was to study *public* risk perceptions. Future research could address how actors that are responsible for energy production – such as the government and industry – incorporate (their interpretation of) public risk perceptions in their own assessment of risks and in risk mitigation policies. For example, a recent

[8] We thank anonymous reviewer for this important point.

study suggests that one of the reasons why there are now more risk mitigation measures in Groningen is that the concerned residents kept emphasizing the urgency of the problem [28]. Future (experimental) studies could systematically test the (causal) relationships between public risk perceptions, on the one hand, and risk perceptions among responsible actors and risk mitigation policies on the other hand. Such research would provide much needed insights into why decision makers choose certain strategies to mitigate (or to not mitigate) the risks of energy production, and help responsible actors assess the effectiveness of risk mitigation policies [29].

In this study, we focused on differences in perceptions of specific types of risks, emotions, and evaluations of different mitigation measures across regions. We did not study individual factors explaining these responses. Future research could study which factors underlie individual differences in the observed perceptions and evaluations, for example the extent to which people feel attached to their region and to the people in their region. Another factor that may influence risk perceptions, emotions, and evaluations of mitigation measures could be how much people trust actors that are responsible for gas production (in this case the government and the company NAM).

5. Conclusion

In conclusion, our research illustrates the added value of systematic social science research in evaluating and deciding upon risky energy production, in addition to media analyses and experts' evaluations of risks. Our findings extended and nuanced media reporting, by demonstrating that people in Groningen perceived particularly high risks for properties and the image of their region. Although current mitigation measures are aimed at addressing these risks, these measures are not seen by people as well implemented. This could be one of the reasons why the perceived risks remain high, next to reoccurring earthquakes and media reports on high risks. This is supported by our finding that people who were not exposed to high risks themselves nevertheless perceived high risks for people in the province of Groningen in general. Furthermore, people particularly felt powerless when thinking about the earthquakes, while other emotional responses were less strong. The perceived risks and negative emotions did not decrease over time, which could be a result of multiple factors, as discussed above. Based on the current findings, we recommend integrating the social science research in the assessment and mitigation of risks posed by energy production.

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Appendix A. The results of MANOVA per phase for differences in the perceived risks of earthquakes between regions, and RM-ANOVA for differences over time.

	(M)ANOVA			RM- ANOVA
	Phase 1 $F(26,294) = 3.40$ (< .001)	Phase 2 $F(26,298) = 4.30$ (< .001)	Phase 3 $F(26,256) = 2.14$ (.001)	
Personal risks				
Damage to house	$F(2158) = 39.62$ (< .001)	$F(2160) = 44.91$ (< .001)	$F(2139) = 11.09$ (< .001)	$F(2260) = 6.39$ (.002)
Drop in house values	$F(2158) = 23.17$ (< .001)	$F(2160) = 24.76$ (< .001)	$F(2139) = 8.73$, (< .001)	$F(1.93,247.05) = 14.85$ (< .001)
Physical injury	$F(2158) = 8.84$ (< .001)	$F(2160) = 18.30$ (< .001)	$F(2139) = 4.12$ (.018)	$F(1.85,240.55) = .70$ (.489)
Stress and worry	$F(2158) = 12.65$ (< .001)	$F(2160) = 13.92$ (< .001)	$F(2139) = 5.71$ (.004)	$F(2260) = 5.98$ (.003)
Reduced quality of living	$F(2158) = 11.19$ (< .001)	$F(2160) = 8.19$ (< .001)	$F(2139) = 3.66$ (.028)	$F(1.86,239.55) = 3.16$ (.048)
Risks for inhabitants of the province of Groningen				
Damage to houses	$F(2158) = 2.50$ (.085)	$F(2160) = 1.05$ (.351)	$F(2139) = .42$ (.656)	$F(2258) = 2.17$ (.116)
Drop in house values	$F(2158) = 2.40$ (.094)	$F(2160) = 2.22$ (.112)	$F(2139) = .40$ (.673)	$F(2258) = 4.92$ (.008)
Physical injury	$F(2158) = 5.36$ (.006)	$F(2160) = 3.11$ (.047)	$F(2139) = 1.98$ (.142)	$F(2262) = 1.54$ (.216)
Stress and worry	$F(2158) = 1.95$ (.145)	$F(2160) = .81$ (.449)	$F(2139) = 1.35$ (.263)	$F(2262) = 2.99$, (.052)
Reduced quality of living	$F(2158) = 2.52$ (.084)	$F(2160) = .48$ (.617)	F(2139) = .08 (.920)	$F(1.82,240.57) = 4.47$ (.015)
Other risks				
Damage to nature and the environment	$F(2158) = 3.11$	$F(2160) = 1.49$	$F(2139) = .55$	$F(2262) = .21$ (.815)

	(.047)	(.228)	(.577)	
Negative image of the province of Groningen	$F(2158) = 4.43$ (.013)	$F(2160) = 2.38$ (.096)	$F(2139) = 1.36$ (.260)	$F(2260) = 8.01$ (< .001)
Impaired relationships between people in one's neighbourhood	$F(2158) = .70$ (.498)	$F(2160) = 2.20$ (.114)	$F(2139) = .68$ (.509)	$F(1.91,251.71) = 1.04$ (.353)

Note: p-values are reported in brackets.

Appendix B. The results of MANOVA per phase for differences in emotions towards earthquakes between regions, and RM-ANOVA for differences over time.

	MANOVA			RM-ANOVA
	Phase 1 $F(14,318) = 3.08$ (< .001)	Phase 2 $F(14,310) = 2.50$ (.002)	Phase 3 $F(14,276) = 1.39$ (.159)	
Fearful	$F(2164) = 11.93$ (< .001)	$F(2160) = 16.81$ (< .001)	Overall model not significant	$F(1.83,242.77) = .10$ (.890)
Angry	$F(2164) = 2.81$ (.063)	$F(2160) = 5.49$ (.005)		$F(2268) = 10.33$ (< .001)
Calm	$F(2164) = 2.77$ (.066)	$F(2160) = .006$ (.994)		$F(2266) = .40$ (.668)
Disappointed	$F(2164) = 2.51$ (.085)	$F(2160) = 5.37$ (.006)		$F(2262) = 9.61$ (< .001)
Uneasy	$F(2164) = 8.86$, (< .001)	$F(2160) = 7.58$ (.001)		$F(2262) = 5.81$ (.003)
Terrible	$F(2164) = 3.33$ (.038)	$F(2160) = 6.59$ (.002)		$F(2256) = 3.57$ (.030)
Powerless	$F(2164) = 2.86$ (.060)	$F(2160) = 5.67$ (.004)		$F(2268) = 3.09$ (.047)

Note: p-values are reported in brackets.

Appendix C. The results of ANOVA per phase for differences in the extent to which respondents thought that gas production should stop or stay the same between regions, and RM-ANOVA for differences over time.

	ANOVA			RM-ANOVA
	Phase 1	Phase 2	Phase 3	
Gas production stop or stay the same	$F(2155) = 3.16$ (.045)	$F(2136) = 3.37$ (.037)	$F(2143) = 7.34$ (.001)	$F(2190) = 6.68$ (.002)

Note: p-values are reported in brackets.

Appendix D. The results of MANOVA for the differences in perceived effectiveness, urgency, and evaluations of implementation of the mitigation measures in phase 2.

	Perceived effectiveness	Perceived urgency	Evaluation of implementation
Reducing gas production around Loppersum	$F(2148) = 3.45$ (.034)	$F(2148) = 1.39$ (.252)	$F(2148) = .44$ (.643)
Reinforcement of houses, buildings, roads and dikes	$F(2148) = .30$ (.744)	$F(2148) = .28$ (.753)	$F(2148) = .70$ (.499)
Adequate regulation for handling damage due to the earthquakes	$F(2148) = .19$ (.828)	$F(2148) = .36$ (.698)	$F(2148) = .29$ (.748)
Adequate compensation for drop in house values due to the earthquakes	$F(2148) = 4.60$ (.012)	$F(2148) = .59$ (.553)	$F(2148) = 2.15$ (.121)
Investing in facilities, such as installing fast internet, improving public transport, and sports and play facilities	$F(2148) = .24$ (.786)	$F(2148) = .44$ (.645)	$F(2148) = 4.24$ (.016)
Investing in local production of renewable energy (for example solar energy)	$F(2) = 1.63$ (.200)	$F(2148) = 3.57$ (.031)	$F(2148) = 10.51$(< .001)
Creating employment by hiring local companies to repair and reinforce houses	$F(2148) = .23$ (.795)	$F(2,148) = .30$ (.738)	$F(2148) = 1.14$ (.323)

Note: p-values are reported in brackets.

References

[1] European Commission, 10. Secure, clean and efficient energy, Horizon 2020 Work Programme 2016–2017, (2016) Decision C(2016)4614 of 25 July 2016.
[2] C. Foulds, T.H. Christensen, Funding pathways to a low-carbon transition, Nat. Energy 1 (2016) 16087.
[3] B.K. Sovacool, Diversity: energy studies need social science, Nature 511 (7511) (2014) 529.
[4] J.I. De Groot, L. Steg, Morality and nuclear energy: perceptions of risks and benefits, personal norms, and willingness to take action related to nuclear energy, Risk Anal. 30 (9) (2010) 1363–1373.
[5] Breakwell, Barnett, (2001), cited in G.M. Breakwell, The Psychology of Risk, 2nd edition. Cambridge University Press, Cambridge, United Kingdom, (2014).
[6] G.T. Gardner, P.C. Stern, Environmental Problems and Human Behaviour, 2nd edition, Pearson Custom Publishing, Boston, MA, 2002.
[7] D.R. Lehman, S.E. Taylor, Date with an earthquake coping with a probable, unpredictable disaster, Pers. Soc. Psychol. Bull. 13 (4) (1987) 546–555.
[8] D.S. Mileti, P.W. O'Brien, Warnings during disaster: normalizing communicated risk, Soc. Probl. (1992) 40–57.
[9] C. Solberg, T. Rossetto, H. Joffe, The social psychology of seismic hazard adjustment: re-evaluating the international literature, Nat. Hazards Earth Syst. Sci. 10 (8) (2010) 1663–1677.
[10] K. Burningham, J. Fielding, D. Thrush, 'It'll never happen to me': understanding public awareness of local flood risk, Disasters 32 (2) (2008) 216–238.
[11] T. Grothmann, F. Reusswig, People at risk of flooding: why some residents take precautionary action while others do not, Nat. Hazards 38 (1–2) (2006) 101–120.
[12] M. Helweg-Larsen, J.A. Shepperd, Do moderators of the optimistic bias affect personal or target risk estimates? A review of the literature, Pers. Soc. Psychol. Rev. 5 (1) (2001) 74–95.
[13] N. Van der Voort, F. Vanclay, Social impacts of earthquakes caused by gas extraction in the Province of Groningen, The Netherlands, Environ. Impact Assess. Rev. 50 (2015) 1–15.
[14] G. Böhm, H.R. Pfister, Action tendencies and characteristics of environmental risks, Acta Psychol. 104 (3) (2000) 317–337.
[15] J.M. Burger, M.L. Palmer, Changes in and generalization of unrealistic optimism following experiences with stressful events: reactions to the 1989 California earthquake, Pers. Soc. Psychol. Bull. 18 (1) (1992) 39–43.
[16] M. Helweg-Larsen, (The lack of) optimistic biases in response to the 1994 Northridge earthquake: the role of personal experience, Basic Appl. Soc. Psychol. 21 (2) (1999) 119–129.
[17] M. Siegrist, Longitudinal studies on risk research, Risk Anal. 34 (8) (2014) 1376–1377.
[18] Centraal Bureau voor de Statistiek(CBS) [Statistics Netherlands], Energieverbruik in Nederland [Energy Use in the Netherlands], (2015) Cited in www.aardgas-in-ndereland.nl . (Accessed 21 March 2016).
[19] Dutch Ministry of Economic Affairs, Energierapport Transitie naar duurzaam [Energy Report Transition to Sustainable], Xerox/OBT, The Hague, 2016.
[20] Dutch Lower House of Parliament, Wijziging van de Mijnbouwwet in verband met nieuwe regels omtrent deelneming in de opsporing en winning van koolwaterstoffen door een daartoe aangewezen vennootschap en omtrent andere taken en activiteiten van die vennootschap – 31 090, nr. 3, SDU uitgevers, The Hague, 2007.
[21] Dutch Lower House of Parliament, Miljoenennota 2016–34 300, nr. 1, (2016).
[22] G. Perlaviciute, L. Steg, E.J. Hoekstra, Is gas perceived as sustainable? Insights from value-driven evaluations in the Netherlands, Energy Res. Soc. Sci. 20 (2016) 55–62.
[23] State Supervision of Mines (SoDM), Reassessment of the Probability of Higher Magnitude Earthquakes in the Groningen Gas Field, (2013) Available via https://www.rijksoverheid.nl/documenten/rapporten/2013/01/16/reassessment-of-the-probability-of-higher-magnitude-earthquakes-in-the-groningen-gas-field . (Accessed 14 April 2016).
[24] Administrative agreement between nine municipalities in the earthquake region, the national government, and the province of Groningen, Herstel van vertrouwen – Vertrouwen op herstel [Recovery of trust - Trust in recovery], (2014) Available via http://www.provinciegroningen.nl/actueel/dossiers/aardbevingen/alles-op-een-rij/ . (Accessed 14 April 2016).
[25] Ministry of Economic Affairs, Winningsbesluit Gaswinning Groningenveld en versterkingsmaatregelen – DGETM-EM/14207601, (2014).
[26] Dutch government, Indeling gemeenten krimpregio's en anticipeerregio's [Distribution of Municipalities in Shrinking Regions and Anticipated Regions], (2015) Available via https://www.rijksoverheid.nl/onderwerpen/bevolkingskrimp/documenten/publicaties/2015/06/29/indeling-gemeenten-krimpregio-s-en-anticipeerregio-s . (Accessed 10 February 2017).
[27] G. Perlaviciute, L. Steg, Quality of life in residential environments, Psyecology 3 (3) (2012) 325–340.
[28] J. Kester, Energy security and human security in a Dutch gasquake context: a case of localized performative politics, Energy Res. Soc. Sci. 24 (2017) 12–20.
[29] P.C. Stern, How can social science research become more influential in energy transitions? Energy Res. Soc. Sci. 26 (2017) 91–95.